Emerging Technology: Vangarde 505: Value Engineering for Pavement Surveys

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Precise pavement surveys are of utmost importance to highway design engineers for several reasons. First, they can locate, identify, and correct roadway deformations in both longitudinal and transverse directions. Crossfall and drainage faults can be corrected. Pavements can be strengthened, and the surveys will identify bridge and overhead structure clearances, as well as locate all warning and safety appliances such as guardrails and signs. It is a questionable design practice to add a new overlay over a flawed roadbed. Pavement roadbeds and structural sections must be evaluated for their ability to handle heavier traffic volumes, drainage, vertical clearances, and safety. Also, accurate volumes must be computed for construction estimates and payment quantities.

Topographic surveys for the engineering and design of pavement overlays provide cost-conscious value engineering. New overlay materials, such as "Stone-Matrix" and plastics may cost as much as $0.40 per square foot, and the over-design for eight lanes of urban interstate can cost as much as $200,000 per mile for 1-1/2 inches of A.C. overlay material. Topographic surveys can also apply to the engineering design for pavement widenings, ramp relocations, the addition of High Occupancy Vehicle (HOV) lanes, or median barrier and drainage improvements. Detailed location of physical features abutting the roadway, including drainage structures, roadway signs, lighting facilities, and right-of-way boundary markers must also be located and their attributes identified and coded into the data collection system.

Data Collection

Today's modern computer-aided highway design programs do not use traditional cross section methods when dealing with the collected field data. They work with horizontal grid coordinates and a Terrain Line Interpolation (TLI) string for the vertical profile. The TLI data is collected in the field by measuring the elevation of a string of points based on a specific interval and any apparent break points in the pavement gradient. The resultant digital terrain model (DTM) provides the basis for all of the design engineering. When using modern electronic data collecting surveying equipment, it is much quicker and more effective to obtain topographic data using the TLI method.

There are several problems associated with obtaining the required digital TLI survey data on active roadways, however. Surveyors are often forced to work on heavily traveled interstates and expressways. In the past two decades, 93 California roadway workers have died, including 54 Caltrans staff. In the period from 1992-1995, four surveyors were killed while performing their duties along California's highways. It is unsafe, not only for surveyors, but for motorists as well. In most cases, one or more lanes must be closed to traffic while the necessary survey data is obtained. For each lane closure, the accident ratio increases by as much as 65 percent, and the motoring public resents the unacceptable traffic delays. There have been recorded incidents when these delays have resulted in cases of "road rage." One lane closure in an urban area, can cost motorists as much as $50,000 in time and money per day. This figure does not take into account the loss caused from personal injury or property damage. In the past, this issue has been addressed in one of three ways:

Do nothing and work from outdated and unreliable as-built plans, using a safe over-design for the pavement reconstruction.

Carry out the required pavement surveys in very unsafe conditions causing great costs and frustration to the motoring public.

Attempt to carry out "field design" during the construction process. This method inevitably causes construction delays and cost over-runs.

In many state DOTs the design engineers are reluctant to request pavement surveys due to the cost to the public and safety hazards to the surveyors. The Department of Transportation of the State of California (Caltrans), along with several other State DOTs are utilizing a unique survey data-collecting technology to provide these much needed pavement surveys—the Vangarde (VG) 505 remote sensing, non-contact survey system. The VG-505 System addresses and solves most of the issues associated with traditional roadway surveying methods.

Developed in the United Kingdom under the trade name "Clear Cone," the VG-505 Survey System is based on a remote sensing, non-contact survey system that allows the execution of a topographic survey of an active roadway surface without interrupting the normal flow of traffic and provides the maximum possible safety to the survey crew and motoring public. One of the most positive aspects is that the VG-505 system collects all highway surface topographic data in one pass of the route. As the VG-505 survey van progresses along the route, the surveyor gathers all topographic data while maintaining horizontal and vertical position at all times. This eliminates the need to establish survey control or run levels prior to conducting the survey. These functions are performed simultaneously with the collection of the topographic data. All observations are taken from within the vehicle at the side of the roadway, greatly increasing worker safety and reducing traffic delays.

Accuracy is as important as safety to a pavement design survey. Without accurate elevations, usually to within ±0.01 feet, the design engineer is unable to make the analysis for drainage design, pavement leveling, and vertical clearances. In May 1990, the Transport and Road Research Laboratory (TRRL), an arm of the British Ministry of Transportation, tested the VG-505 System; the Caltrans Geometronics Branch tested it in 1992. The distance bands of the test ranged from 5 to 50 meters, with the root mean square error of the measured pavement elevations being less than 2 millimeters.

The VG-505 System deals with the quality assurance issue by using software programming and a systems approach to the work. First, primary survey control is generally established using GPS methods. The GPS control points are normally established 2-3 kilometers apart and tied to the project's horizontal and vertical control net. Permanent Ground Monuments (PGM) are then set at ±100 meter staggered intervals along both shoulders, or close by. PGMs, pavement, and topographic measurements are all taken at the same time and recorded directly to the system's onboard computer through its link to the digital survey instruments. Each computer recorded measurement is made twice and self-checked (by the software) in the field against its own value. The residual errors are displayed after each measurement, and if they are out of a preset range, the system will not accept the values and the measurement must be taken again. As a final quality assurance measure, a CAD-generated plot is made at the end of each working day from the collected data. This plot is a visual check of the day's work and will graphically show any vertical or horizontal deviations in the survey. All observations are collected during one pass of the route and there is no need to return for horizontal and vertical control. According to Greg Leggett, Caltrans transportation surveyor and the crew chief for the VG-505 unit in District 7, normal horizontal closures exceed 1:30,000 and vertical closures are within 15 millimeters.

In July of 1992, Caltrans conducted benchmark testing and demonstration projects of the VG-505 system. This originated when Larry Fenske, Chief of the Headquarters Geometronics Branch started working with the British firm of Longdin & Browning and the California firm of Psomas on the development of the system for California. A benchmark test was conducted on a new, un-opened section of the I-105 freeway in Los Angeles. Two demonstration projects were then carried out by Psomas, entailing the survey of six miles of existing 8-lane freeway with some of the highest traffic volumes in the nation. In early 1993 Caltrans endorsed the system and adopted a policy recommending its use for all pavement surveys in urban areas or heavily traveled rural roads (Pavement Elevation Surveys–Methods & Guidelines, June, 1993. Supplement 93-1 to Caltrans Survey Manual).

The VG-505 system is comprised of a modified one-ton air conditioned van, special hydraulic stabilizers and tripod, a revolving turret, a patented linkage of a Leica T-1600 digital theodolite, a Leica DIOR reflectorless EDM, a special collimator scope, a notebook PC, and special proprietary data collecting and traversing software.

How It Works

A typical VG-505 proceeds as follows: Project control is established with GPS and is normally tied to the State Plane Coordinate System for horizontal position and local project vertical control. The VG-505 crew then sets a series of PGMs at 100-meter spacing or at such spacing where there will always be three intervisible points. The VG-505 van is then positioned at the beginning of the project and the hydraulic tripod is lowered to the pavement and firmly set. The van stabilizers are set to reinforce the stability of the van to reduce movement caused by wind or passing trucks. The instrument operator then takes position in the moveable turret and sights the first two project control points and three PGMs. The points are read and a resection based horizontal and vertical traverse is started. These observations set the position of the instrument and the traverse is carried in the computer. Side shots are then taken to selected points on the pavement and any required feature points such as curbs, drainage structures, signs, guardrails, bridge columns and sofits, light poles, etc. All feature points are coded for identification in the database and will be reproduced in the DTM. Once all of the observations have been taken from one position, the van is moved forward about 130 meters to the next

observation point. As there is about a 10-meter zone surrounding the van caused by interference from the van itself, the operator must plan his moves to provide coverage of these "Blacked Out" areas. Once the van has been repositioned, the set-up process is repeated and observations are taken to at least 3 PGMs to connect the traverse. This process is repeated until the end of the project is reached and the traverse is closed to the preset project control. The error of closure is determined and, if it is within the acceptable range, a least squares adjustment is carried out on all observed points, including side shots. Once this is completed, the surveyor can generate a screen plot to check for spikes or anomalies in the data. If all of the data looks good, a DTM can be created. For the DTM process, Caltrans used a CAD package called CAiCE. This file is provided to the engineers, and they may begin their design work using a very complete and reliable digital model of the project.
According to studies of conventional survey productivity rates compared to VG-505 productivity rates, there is a savings of approximately 20 percent. The VG-505 System is procedure-based with fewer variables than the traditional method, so production rates may be determined with more accuracy.
It should be pointed out that Caltrans is the only DOT in the United States to own and operate the VG-505 system. Other DOTs, such as North Carolina, Florida, Delaware, Maryland, Georgia, Illinois, and Ohio utilize the VG-505 system through survey consultants who have the system. The only firms that I know of that have a VG-505 system are URS and PBSJ.
Many factors must be considered when factoring total cost savings. Pavement surveys made with the VG-505 System are generally less than traditional EDM total station methods. When traffic management is factored in, the cost for the traditional survey work will increase dramatically. In high traffic volume, urban areas traffic management can be as much as $3,000 for a six-hour working day. The total cost to the public and taxpayers is another matter. The use of the VG-505 survey system provides the transportation design engineer with a cost-effective, accurate, and efficient means of obtaining the field information needed for value-added engineering design. It provides the field surveyor with a safe, comfortable working environment and keeps the roadway free of traffic cones, delays, and accidents.

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